Anatomic variations of pudendal nerve within pelvis and pudendal canal: clinical applications

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OBJECTIVE: The objective of the study was to examine the anatomic variation of the pudendal nerve in the pelvis, on the dorsal surface of the sacrospinous ligament, and in the pudendal canal.

STUDY DESIGN: Detailed dissections of the pudendal nerve were performed in unembalmed female cadavers. Pelvic measurements included the distance from the origin of the pudendal nerve to the tip of ischial spine and the nerve width at its origin. The length of the pudendal canal was measured. The inferior rectal nerve was identified in the ischioanal fossa and its course documented. Lastly, the relationship of the pudendal nerve to the dorsal surface of the sacrospinous ligament was examined after transecting the lateral surface of the sacrospinous ligament. Descriptive statistics were used for data analyses and reporting.

RESULTS: Thirteen female cadavers (26 hemipelvises) were examined. A single pudendal nerve trunk was identified in 61.5% of hemipelvises. The median distance from the point of the pudendal nerve formation to the ischial spine was 27.5 mm (range, 14.5—37 mm). The width of the pudendal nerve in the pelvis was 4.5 mm (range, 2.5—6.3 mm). The length of the pudendal canal was 40.5 mm (range,

20.5—54.5 mm). The inferior rectal nerve was noted to enter the pudendal canal in 42.3% of hemipelvises; in these cases, the nerve exited the canal at a distance of 32.5 mm (range, 16—45 mm) from the ischial spine. In the remaining specimens, the inferior rectal nerve passed behind the sacrospinous ligament and entered the ischioanal fossa without entering the pudendal canal. In all specimens, the pudendal nerve was fixed by connective tissue to the dorsal surface of the sacrospinous ligament.

CONCLUSION: Great variability exists in pudendal nerve anatomy. Fixation of the pudendal nerve to the dorsal surface of the sacrospinous ligament is a consistent finding; thus, pudendal neuralgia attributed to nerve entrapment may be overestimated. The path of the inferior rectal nerve relative to the pudendal canal may have implications in the development of anorectal symptoms. Improved characterization of the pudendal nerve and its branches can help avoid intraoperative complications and enhance existing treatment modalities for pudendal neuropathy.

Key words: anatomic variation, inferior rectal nerve, pudendal nerve, pudendal neuralgia

Pudendal neuralgia is characterized as a painful, neuropathic condition in the distribution of the pudendal nerve (PN). Injury to the pudendal and other lumbosacral nerve plexus branches can result from several etiologies, including vaginal delivery, pelvic surgery, intraoperative patient positioning,

trauma, chronic compression, and pelvic tumors.

The true incidence of pudendal neuralgia in the general population is unknown but is estimated to be approximately 1%.[1] Diagnosis may be facilitated by use of the Nantes criteria, which utilizes the following 5 essential clinical measures: pain in the anatomic distribution of the pudendal nerve, pain with sitting, pain that does not provoke waking at night, no sensory loss on physical examination, and positive response to pudendal nerve block.[2] Although pudendal neuralgia is uncommon, the impact of this condition on affected patients and clinicians participating in their care is significant.

The PN provides both motor and sensory innervation to the perineal region. The nerve is formed from contributions of the ventral rami of the second, third, and fourth sacral nerves (S2-4).[3] Once formed, the PN courses between

the piriformis and coccygeus muscles. It then exits the pelvis through the greater sciatic foramen, courses on the posterolateral surface of the sacrospinous ligament (SSL), and enters the perineum through the lesser sciatic foramen. In the perineum, the PN promptly enters the pudendal (Alcock's) canal along the lateral wall of the ischioanal fossa. The pudendal canal is formed by a splitting of the fascia covering the medial aspect of the obturator internus muscle.

Classically, a single common PN trunk terminates by dividing into 3 branches, the dorsal nerve of the clitoris, the perineal nerve, and the inferior rectal nerve (IRN).[3] However, reports demonstrate variability in PN branching pattern, with up to 3 PN trunks differentially contributing to its terminal branches.[4-10]

Injury to the PN may result from a variety of mechanisms. These include direct or stretch injury and nerve

FIGURE 1
Lumbosacral and pudendal nerve anatomy
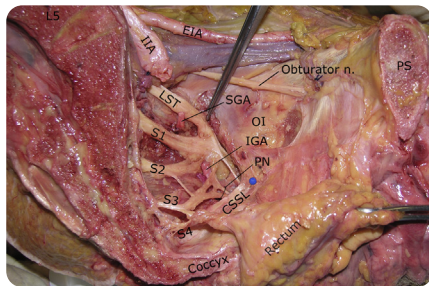
Medial view of dissected left hemipelvis illustrating exposed LST, the first through fourth sacral nerves (S1—S4), and PN. *Blue pin* indicates the ischial spine.

CSSL, coccygeus-sacrospinous ligament complex; *EIA*, external iliac artery (cut); *IGA*, inferior gluteal artery (cut); *IIA*, internal iliac artery (cut); *L5*, fifth lumbar vertebra; *LST*, lumbosacral trunk; *OI*, obturator internus muscle; *PN*, pudendal nerve; *PS*, pubic symphysis; *SGA*, superior gluteal artery (cut).

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compression or entrapment. Whereas the PN may sustain direct injury anywhere along its course, areas suspected to be at risk for nerve entrapment include the region between the sacrospinous and sacrotuberous ligaments, the pudendal canal, and the inferior surface of the pubic ramus.[4]

Neuroma formation from compression or direct injury of the pudendal nerve during pelvic surgery has been implicated in the genesis of pudendal neuralgia.[11] During childbirth, the nerve is thought to be at risk of injury during downward displacement of the pelvic floor and perineal structures because the nerve's course is related to fixed structures such as the dorsal surface of the sacrospinous ligament and the pudendal canal. However, descriptions of the relationships between the PN and its surrounding connective tissue are limited. These relationships may offer insight regarding the mobility of the nerve during its long and complex path.

Interventional therapeutic modalities for pudendal neuralgia include imaging-guided nerve block injections. Magnetic resonance neurography—guided pudendal nerve block has recently been described and is believed to provide high technical accuracy.[12] These treatments are limited by the variability in pudendal nerve anatomy and difficulty in accurately visualizing the smaller terminal branches radiographically.

In patients with refractory pudendal neuralgia, decompression surgery has been described as a surgical treatment option but its use remains controversial.[13,14] Further descriptions of variability in PN anatomy and a better understanding of the nerve to connective tissue interactions are necessary to optimize treatment modalities and to explore mechanisms of nerve injury.

The objectives of this cadaver study were to further examine the variability in pudendal nerve branching patterns within the pelvis and pudendal canal and to describe the relationship of the pudendal nerve to adjacent connective tissue within the pudendal canal and behind the sacrospinous ligament.

MATERIALS AND METHODS
Detailed dissections were performed in 13 unembalmed female cadavers obtained from the Willed Body Program at the University of Texas Southwestern Medical Center in Dallas. This study was exempt from review by the University of Texas Southwestern Medical Center Institutional Review Board in accordance with the Code of Federal Regulations, Title 45. Age, race, height, weight, and cause of death were obtained for all cadavers.

Pudendal nerve dissections were completed bilaterally through a transabdominal (pelvic) and perineal approach. Cadavers were transected above the level of the aortic bifurcation and at midthigh. Each specimen was further transected in the midsagittal plane to facilitate dissection. The peritoneum overlying the sacrum and the fascia covering the piriformis muscles were carefully dissected to expose the lumbosacral trunk (LST) and sacral nerve roots (S1-S5) (Figure 1). The relationship of the superior and inferior gluteal and internal pudendal arteries to the nerve branches as the vessels exited the pelvis were documented. The width of the LST as it crossed over the pelvic brim and the widths of the S1 to S5 nerves 1 cm from the point at which they emerged from the anterior sacral foramina were recorded.

The course of the sacral nerves was followed and their contribution to the formation of the pudendal nerve within the pelvis was documented. The point at which branches of S2, S3, and S4 converged to form the pudendal nerve was labeled and designated the origin of the pudendal nerve. The PN was examined in the following 3 regions: (1) pelvis, (2) dorsal surface of the

TABLE
## Widths of the lumbosacral trunk, sacral nerves, pudendal nerve, and inferior rectal nerve in the pelvis

Variable	Median width, mm, and range		
	Left side	Right side	Combined
Lumbosacral trunk	9.0 (6—13.5)	10.5 (5.3—14.5)	9.8 (5.3—14.5)
Sacral nerves			
S1	8.0 (6.5—9.5)	8.0 (5.5—10)	8.0 (5.5—10)
S2	6.0 (4.5—8)	6.0 (4.8—8)	6.0 (4.5—8)
S3	4.0 (3—5)	4.0 (2.8—6)	4.0 (2.8—6)
S4	2.0 (1—4)	2.0 (1—3)	2.0 (1—4)
S5[a]	1.3 (0.5—2)	0.5 (0.5—0.5)	0.8 (0.5—2)
Pudendal nerve	5.0 (2.5—6.3)	4.3 (2.5—6)	4.5 (2.5—6.3)
Inferior rectal nerve	3.0 (1—4)	3.0 (1—4)	3.0 (1—4)

[a] When identification was possible.

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FIGURE 2
Gluteal and pudendal artery anatomy
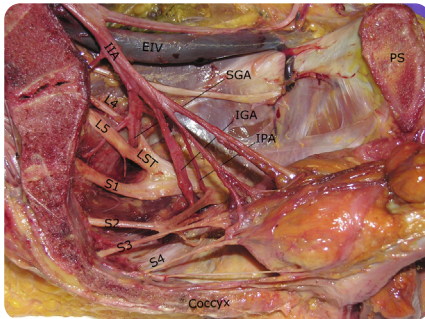
Dissected left hemipelvis demonstrate the relative location of the SGA, IGA, and IPA to the lumbosacral nerves.

EIV, external iliac vein; *IGA*, inferior gluteal artery; *IIA*, internal iliac artery; *IPA*, internal pudendal artery; *L4* and *L5*, fourth and fifth lumbar nerves; *S1-S4*, first through fourth sacral nerves; *SGA*, superior gluteal artery.

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sacrospinous ligament, and (3) pudendal canal.

Pelvic measurements obtained included the distance from the origin of the PN to the tip of the ischial spine (IS) and the PN width at its origin. When more than 1 branch of the PN was noted within the pelvis, the number and width of the branches were recorded. The distance from the IS to the medial aspect of the S4 foramina was used as a surrogate estimate of the SSL length. The height of the SSL at its midpoint was recorded.

The medial border of the obturator internus muscle within the perineum was exposed by transecting the levator ani muscles medial and parallel to the arcus tendineus fascia pelvis. This permitted inferior and medial access and evaluation of the pudendal canal. The fatty tissue within the ischioanal fossa was removed to expose the IRN, pudendal canal, and other branches of the pudendal nerve as they emerged from the canal.

The length of the pudendal canal was measured from the tip of IS to the point at which the largest PN branch (other than the IRN) emerged. The IRN was identified adjacent to the anus, followed proximally, and its entry into the

pudendal canal was documented. The distance from the IS to the point at which the IRN exited the canal was recorded. The width of the IRN was measured as it emerged into the ischioanal fossa.

The SSL was then transected approximately 1 cm medial to its attachment to the IS and the medial cut edge of the ligament was reflected medially to expose the pudendal nerve in this region. Special attention was given to examining the attachments of the pudendal nerve to surrounding connective tissue in all three regions. The mobility or freedom of movement of the nerve in a specific region (pelvic, SSL, pudendal canal) was assessed by applying gentle traction proximal and distal to the area being examined.

Mobility of the nerve was first assessed in the pelvis, then the pudendal canal, and lastly behind the SSL. Displacement of the nerve proximal to the point of traction was interpreted as a positive sign of mobility. Photographs of all dissections were taken for documentation. All measurements were taken twice with a caliper and plastic ruler. Measurements were tabulated and descriptive statistics were used for data analyses and reporting.

RESULTS
Thirteen unembalmed female cadavers (26 hemipelvises) were examined. All

cadavers were white, with a median age of 81.7 years (range, 61–95 years). The median body mass index was 18.9 kg/m^2 (range, 13.5–24.9 kg/m^2). The most common cause of death was cancer (lung and breast). Dissections and available medical histories revealed no obvious signs of pelvic pathology such as cancer, fractured pelvic bones, or prior trauma.

The widths of the LST, S1-5 nerves, PN, and IRN are shown in the Table. The superior gluteal artery exited the pelvis between the LST and S1 nerves in 69.2% (n = 18) (Figure 1) and above the LST or between the fourth and fifth lumbar nerves in 30.8% (n = 8) (Figure 2) of hemipelvises. The inferior gluteal artery exited the pelvis between S2 or S3 branches in the majority of specimens (Figure 1) but occasionally between S1 and S2 branches (Figure 2). In all specimens, the internal pudendal artery exited lateral to the inferior gluteal artery and in close proximity to the IS (Figure 2). The median length of the SSL was 60.8 mm (range, 52–78.5 mm) and its median height at its midpoint was 20 mm (range, 12.5–24.5 mm).

In all specimens, the PN was formed from contributions of S2, S3, and S4 nerves (Figure 1). From its point of formation in the pelvis to its division into terminal branches, a single PN trunk was identified in 61.5% (n = 16) of hemipelvises (Figure 3). In the remaining
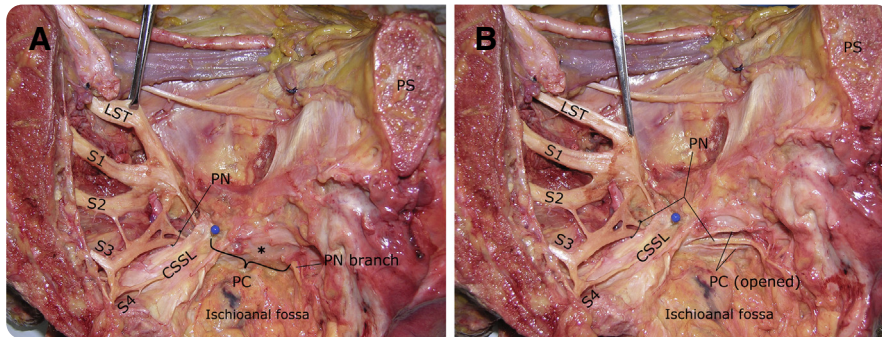
FIGURE 3
Pudendal nerve trunks
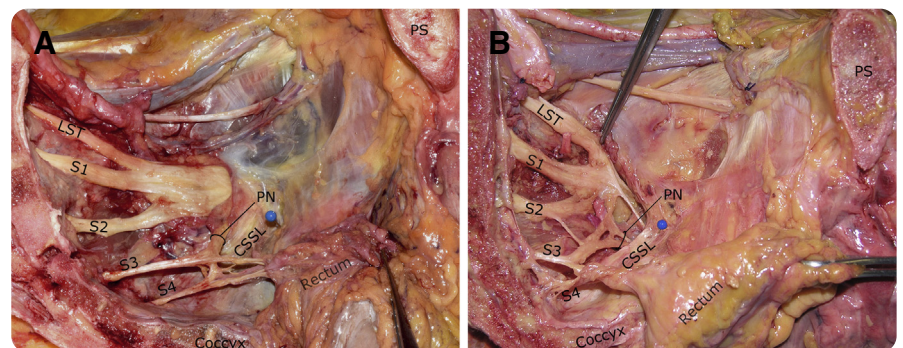
Dissected left hemipelvises showing **A,** a single PN trunk and **B,** multiple PN trunks. *Blue pin* indicates the ischial spine.

CSSL, coccygeus-sacrospinous ligament complex; *PN*, pudendal nerve.

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FIGURE 4
Pudendal canal anatomy

A, The PC on the lateral wall of the left ischioanal fossa is shown. **B,** The PC opened to expose the PN and vessels. The *asterisk* indicates the medial fascia of the obturator internus muscle; the *blue pin* indicates the ischial spine.

CSSL, coccygeus-sacrospinous ligament complex; PC, pudendal canal; PN, pudendal nerve.

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hemipelvises (n = 10), multiple PN trunks were identified, 70% (n = 7) within the pelvis or behind the IS and 30% (n = 3) within the pudendal canal.

The median distance from the origin of the PN to the tip of the IS was 27.5 mm (range, 14.5–36.5 mm) on the left and 27.8 mm (range, 19.5–37 mm) on the right side. The pudendal canal was formed by dense connective tissue converging with the medial border of the obturator internus fascia (Figure 4). The median length of the pudendal

canal, measured from tip of IS to the point at which the largest terminal PN branch emerged was 40.0 mm (range, 20.5–49 mm) on the left and 40.5 mm (range, 23.5–54.5 mm) on the right side. In all specimens, the PN was fixed by connective tissue to the dorsal surface of the SSL (Figure 5).

Traction on the nerve(s) within the pudendal canal did not result in displacement of the pelvic section of the nerve, and similarly, traction on the pelvic portion of the PN did not result in

movement of the nerve(s) within the canal. The PN was not freely mobile until the SSL was transected from its attachment to the IS, and the nerve was dissected off its surrounding connective tissue fibers.

The IRN was noted to enter the pudendal canal in 42.3% (n = 11) of hemipelvises (Figure 6). In these cases, the nerve exited the canal at a distance of 32.5 mm (range, 16–45 mm) from the IS. In the remaining specimens, the IRN passed behind the SSL and entered the ischioanal fossa without entering the pudendal canal.

COMMENT
In this cadaver study, we provide detailed descriptions of the pudendal nerve in the pelvis, dorsal to the sacrospinous ligament complex, and in the pudendal canal. Our findings demonstrate high variability in the branching patterns of the PN and in the course of the IRN. In addition, our dissections reveal relative fixation of the PN through connective tissue attachments on the dorsal surface of the SSL and in the pudendal canal.

Our study supports descriptions of variability in the branching pattern of the pudendal nerve. Mahakkanukrauh et al[5] reported that 43.8% of PNs examined had multiple trunks, whereas Gruber et al[15] found 40.5% with multiple trunks. Similarly, we found that approximately 38% of hemipelvises had multiple PN trunks.

Similar to previous cadaver studies documenting the mean diameter of the PN to be between 4.67 and 5.05 mm, we noted that at the point of formation, the median PN width was 4.5 mm.[5,16] These findings have important clinical implications and may be useful for surgeons performing suspension procedures utilizing the SSL or in localizing the PN during diagnostic and/or therapeutic procedures.

The pudendal canal is thought to represent a potential area of nerve injury or entrapment.[4] We found the dissection and precise characterization of the extent and boundaries of the pudendal canal to be challenging. Our approach to these dissections was to transect the levator ani muscles medial and parallel to the arcus

FIGURE 5
Pudendal nerve mobility
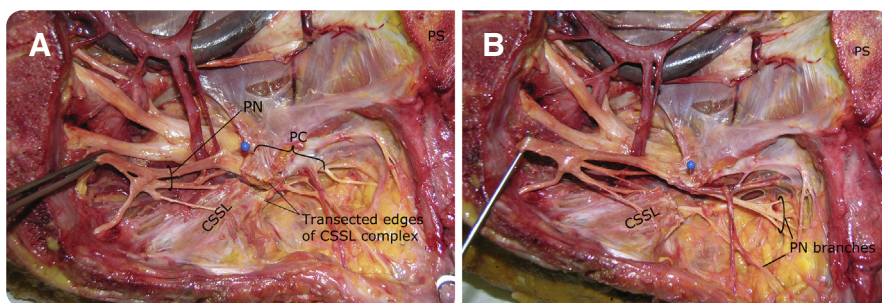
A, Transection of the left CSSL complex 1 cm medial to the ischial spine (*blue pin*) exposes the PN and vessels on dorsal surface of SSL. Note that the PN appears fixed by connective tissue to the dorsal surface of SSL. **B,** Complete mobilization of the PN and vessels following further dissection from connective tissue within the PC and on the dorsal surface of the SSL.

CSSL, coccygeus-sacrospinous ligament complex; PC, pudendal canal; PN, pudendal nerve; SSL, sacrospinous ligament.

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tendineus fascia pelvis, allowing for inferior and medial entry to the pudendal canal, in an attempt to preserve the integrity of the pudendal canal.

Consistent with prior descriptions, we noted that within the pudendal canal, the nerves and vessels were surrounded by a connective tissue sheath.[4,9] Our median pudendal canal length was 4.0 cm. Previous descriptions are unclear on precise measurement techniques but the reported pudendal canal lengths range from 1.6 to 5.5 cm.[5,7,9-10,16,17] This wide range of measurements may be partly attributed to the landmarks used to define the pudendal canal, which, in our study, included the tip of the IS and the point at which the largest terminal branch (other than the IRN) emerged.

Relationships between the IRN and the PN are important in evaluating the anorectal symptoms of pudendal neuralgia. Large variability exists when describing the course of the IRN and its position relative to the pudendal canal. Prior anatomic studies report that the IRN enters the pudendal canal in 56–90% of specimens.[7,9,10] We found that the IRN entered the pudendal canal in 42% of hemipelvises.

During labor and delivery, the PN and its branches may be injured by either compression or stretch. The perineal branch of the PN may provide some innervation to the striated urogenital sphincter, and injury to this branch can be associated with stress urinary incontinence.[10] In contrast to the IRN, the perineal branch generally courses within the pudendal canal. The IRN provides innervation to the external anal sphincter, and injury to this structure may lead to fecal incontinence.

One could argue that the IRN is protected against compression injury in bypassing the pudendal canal. In fact, some have speculated that patients in whom the IRN does not enter the pudendal canal are spared from the anorectal symptoms of the pudendal canal syndrome.[7] However, when the IRN does not enter the canal, its proximal course is deeper in the ischioanal fossa, close to the inferior surface of the pelvic floor muscles and thus potentially at risk for stretch injury.[9] Radiographic studies
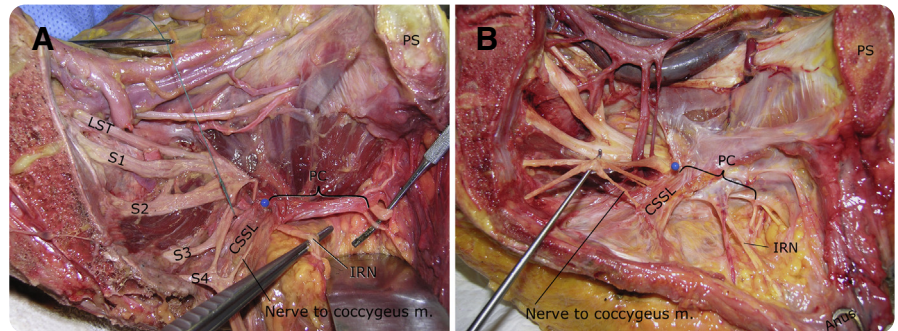
A, The IRN emerges from the dorsal surface of the left CSSL complex and courses within the ischioanal fossa without entering the PC. **B,** The IRN courses through the proximal portion of the PC before exiting into the ischioanal fossa and coursing toward the anorectum.

CSSL, coccygeus-sacrospinous ligament; *IRN,* inferior rectal nerve; *PC,* pudendal canal.

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that demonstrate the position of the IRN relative to the canal would be useful in understanding the relationship of post-partum fecal incontinence with the anatomic path of the nerve.

An interesting finding of this study was the fixation of the PN on the dorsal surface of the SSL. These connective tissue attachments were found not only on the dorsal surface of the SSL-IS junction but within the pudendal canal. Whereas previous authors have noted that the PN is surrounded by a connective tissue sheath in the pudendal canal,[4,9] we found no specific descriptions or assessments of the mobility or connective tissue interactions of the PN on the dorsal surface of the SSL.

This finding has potential implications in the surgical treatment of pudendal neuralgia, and it may be misleading to attribute pudendal neuralgia to nerve entrapment. Thus, procedures seeking to decompress the PN may not address the true etiology. In fact, these procedures may potentially result in significant complications, given the complexity of surrounding nerve and vascular anatomy.

There are inherent limitations to the use of cadavers for investigating surgical anatomy, including tissue deterioration and absence of muscular tone. Generalizability of our findings may be limited because all specimens were white and of older age and with a lower body mass

index. In addition because only 13 specimens were examined, the range of anatomic variability should be confirmed with larger anatomic studies. Lastly, the effect of aging on nerve and connective tissue anatomy is unclear.

Managing patients with pudendal neuralgia represents a significant clinical challenge. As health care providers, we should carefully weigh the risks and benefits of interventional procedures with limited clinical efficacy and potential for significant complications. A comprehensive knowledge of the complex pudendal nerve anatomy is essential in optimizing diagnostic and treatment modalities. ∎

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